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5 JAN 1948

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RESEARCH MEMORANDUM

for the

Bureau of Ships, Navy Department

CLASSIFICATION CANCELLED
Authority NACA R7 2976 Date 4/14/55
By NASA 4/26/55 See

TESTS OF THE AN/SPS-1 RADAR ANTENNA IN THE LANGLEY FULL-SCALE TUNNEL

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NATIONAL ADVISORY COMMITTEE
FOR AERONAUTICS

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TESTS OF THE AN/SPS-1 RADAR ANTENNA IN THE LANGLEY FULL-SCALE TUNNEL

By Ralph W. May, Jr.

SUMMARY

Tests have been conducted to determine the drive-motor torque and the static force and moment characteristics of the AN/SPS-1 radar antenna. Shifting the longitudinal position of the antenna had very little effect on the drive-motor torque, which reached a maximum value expressed in terms of dynamic pressure $(T/q)_{max}$ of 1.15 at an azimuth angle of 245°. The maximum observed values of rolling, pitching, and yawing moments in terms of dynamic pressure are -29.0, 66.6, and 13.4, respectively.

INTRODUCTION

A radar antenna operating at the top of a ship's mast is subjected to varying wind and acceleration loads which must be overcome by stabilizing mechanisms that keep the antenna level at all attitudes of the vessel in pitch and roll. Since the acceleration loads vary directly with the antenna weight, the weight of the drive-motor and stabilizing systems must be as light as possible and yet be adequate to provide the required performance. In order to provide design data, tests of a mock-up of the AN/SPS-1 radar antenna have been conducted in the Langley full-scale tunnel at the request of the Bureau of Ships, Navy Department, to determine (1) the variation of maximum drive-motor torque with longitudinal position of the antenna, (2) the variation of the drive-motor torque with azimuth angle, and (3) the static forces and moments about the gimbal location of the proposed antenna stabilizing system.

The AN/SPS-1 radar antenna is a ship-borne unit incorporating individual air-search, surface-search, and recognition antennas. The antenna must be capable of operating at a speed of approximately 13 rpm at wind velocities of 60 knots and, also, of structurally withstanding wind velocities up to 90 knots.

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SYMBOLS

The positive direction of all forces, moments, and angles is shown in the sketch of figure 1. Moments were calculated about the gimbal location of the proposed stabilizing system.

D	drag, pounds
L	lift, pounds
Y	side force, pounds
M_x	rolling moment, pound-feet
M_y	pitching moment, pound-feet
M_z	yawing moment, pound-feet
T	drive-motor torque, ounce-feet
ψ	azimuth angle, degrees (0° with antenna facing directly upstream)
x	distance of antenna rearward from full forward position, inches
q	dynamic pressure, pounds per square foot $\left(\frac{\rho}{2V^2}\right)$

where

ρ	mass density of air, slugs per cubic foot (0.002378 at standard sea-level conditions)
V	wind velocity, feet per second

APPARATUS AND TESTS

The AN/SPS-1 antenna test mock-up is shown mounted in the Langley full-scale tunnel in figure 2, and a three-view drawing of the antenna giving the principal dimensions and essential nomenclature is presented in figure 3. The proposed production model is dimensionally similar to the test mock-up shown in figures 2 and 3 except for the pedestal. The test mock-up pedestal incorporates only a drive mechanism with a 1/4-horsepower motor and gear reduction system; whereas the actual antenna will possess in addition a stabilizing mechanism that hinges around a gimbal located on the center of rotation and 8 inches below the assembly base plate of the antenna (fig. 3). The test mock-up has adjustable 6-inch slots in the antenna assembly base plate and in the surface-search-antenna support arms so that the surface-search unit can be maintained at a set distance of 26.5 inches (fig. 3) from the center of rotation while the remainder of the antenna assembly is shifted longitudinally.

The wind-tunnel investigation included both dynamic and static tests. In the dynamic tests, first, the variation of maximum drive-motor torque was obtained while the antenna position, except for the surface-search unit, was shifted longitudinally with respect to the center of rotation. Although design specifications required that the surface-search unit be held at a distance of 26.5 inches from the center of rotation, one run was made to determine the effect of shortening the distance to 24.5 inches. Because of the uncertainty of being able to shorten the distance on the production model of the AN/SPS-1 radar antenna, however, the rest of the tests were run with the surface-search unit maintained at the prescribed distance of 26.5 inches and the antenna set at the position showing minimum peak torque requirements. Secondly, the variation of motor torque required to overcome wind loads was determined for a complete azimuth range at wind velocities of 47 and 72 feet per second. The static tests consisted of six-component force and moment measurements at wind velocities of 72 and 99 feet per second with the antenna locked at 10° intervals through an azimuth range of from 350° to 190°.

In the dynamic tests with the antenna rotating in the air stream at an average speed of about 13 rpm, simultaneous values of azimuth angle, motor speed, and motor power input were recorded by camera. The azimuth angle, rotational speed, and power input were determined by an autosyn arrangement, an electrical tachometer, and a wattmeter, respectively. Prior to the wind-tunnel investigation, the 1/4-horsepower drive motor was calibrated to obtain the torque-speed and power-speed curves of figure 4. Before each dynamic test, the voltage was regulated by means of a variac so that the simultaneous steady values of power and motor speed fell on the power-speed curve of figure 4. This specific voltage was maintained throughout the test as the tunnel was operated. Motor-torque values corresponding to the values of motor speed recorded during the tests were then determined from the torque-speed calibration curve of figure 4. All torque data, except that used in determining the variation of peak motor torque with longitudinal antenna position, have been corrected for the tare torque resulting from gear train loss.

The full-scale-tunnel balance system described in reference 1 was used for the static test measurements. All static data have been corrected for the tare caused by the part of the cylindrical pedestal protruding above the tear-drop fairing. The tare of the pedestal was obtained with the antenna removed from the pedestal and the large horizontal cut-out in the mounting ring covered.

RESULTS AND DISCUSSION

Dynamic Tests

The variation of maximum drive-motor torque with longitudinal position of the AN/SPS-1 radar antenna is shown in figure 5 to be very small, with values of $(T/q)_{max}$ (including gear train loss) ranging only from 3.04 with the antenna full forward to 2.99 with the antenna full back. Although shortening the length of the surface-search-antenna support arms 2 inches decreased $(T/q)_{max}$ 2.2 percent, the surface-search unit was maintained at the specified distance of 26.5 inches from the center of rotation for the rest of the tests.

The wind-load torque curves of figure 6 indicate a rather large torque decrease, especially in the azimuth range having high positive torque values, as the wind velocity is increased from 47 to 72 feet per second. Although both curves show a corresponding variation of T/q with azimuth angle, the 72-foot-per-second curve is believed to be somewhat in error because at this wind velocity the 1/4-horsepower drive motor of the test mock-up becomes magnetically saturated in the azimuth regions of high torque and the inertia forces keep the antenna rotating. Also, the drive-motor speed-torque curve of figure 4 could be in error in the stall speed range because the curve had to be estimated in that speed range where calibration points were not available.

The antenna experiences high wind-load torque through an azimuth range of from about 220° to 330° as the surface-search unit comes into the air stream. A peak value of T/q of 1.15 due to wind loads is reached at an azimuth angle of about 245° (fig. 6). Another azimuth region of high torque is from approximately 40° to 80° where the retreating surface-search unit does not supply enough balancing torque to counteract the torque required by the remaining part of the antenna. A fairing on the back of the leading side of the surface-search unit should decrease the torque required through the azimuth range from 220° to 330° and also should decrease the torque in the 40° to 80° azimuth range if the back of the fairing were made to provide added effective flat-plate area to the surface-search unit as it retreats in the second quadrant.

Static Tests

The variations of the drag, lift, and side force, and the rolling, pitching, and yawing moments about the gimbal location are shown in figure 7 for wind velocities of 72 and 99 feet per second. The maximum observed values of the forces and moments expressed in terms of dynamic pressure and the corresponding azimuth angles are given in the accompanying table:

Force or moment in terms of q	Maximum observed value	Azimuth angle (deg)
D/q	26.8	350
L/q	-7.7	188
Y/q	-10.9	42
M_X/q	-29.0	54
M_Y/q	66.6	357
M_Z/q	13.4	89

Increasing the wind velocity has no consistent effect on the static force and moment functions except for slightly increasing the rolling moment M_X/q and slightly decreasing the yawing moment M_Z/q. The drag and pitching moments attain their greatest values at approximately 0°, have minimum values at 90°, and again reach second but lower positive peaks at 180° azimuth (figs. 7(a) and 7(e)). The side-force and rolling-moment variations are essentially 2-cycle sine variations (figs. 7(c) and 7(d)) having negative peaks at 40° to 55° and positive peaks at 135° to 140° azimuth angles. The maximum positive values of side force Y/q and rolling moment M_X/q in terms of dynamic pressure are only 8.4 and 26.3, respectively, compared with -10.9 and -29.0 for the respective maximum negative values. Values of the yawing moment M_Z/q in terms of dynamic pressure, which are indicative of the drive-motor starting torque requirements, are in excess of 5 through an azimuth range of approximately 60° to 170° (fig. 7(f)). The lift variation given in figure 7(b) is only of secondary importance.

SUMMARY OF RESULTS

The significant results of the AN/SPS-1 radar-antenna tests in the Langley full-scale tunnel may be summarized as follows:

1. Shifting the longitudinal position of the antenna has very little effect on the drive-motor torque requirements.

2. The drive-motor torque resulting from wind loads is high in the azimuth range of from 220° to 330° and from 40° to 80° and reaches a maximum value, expressed in terms of dynamic pressure $(T/q)_{max}$, of 1.15 at 245° azimuth.

3. The maximum observed static values of rolling moment M_X/q and pitching moment M_Y/q in terms of dynamic pressure about the gimbal location of the proposed antenna stabilizing system are -29.0 and 66.6, respectively. The maximum observed static yawing moment in terms of dynamic pressure M_Z/q is 13.4.

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bbs

REFERENCE

1. DeFrance, Smith J.: The N.A.C.A. Full-Scale Wind Tunnel. NACA Rep. No. 459, 1933.

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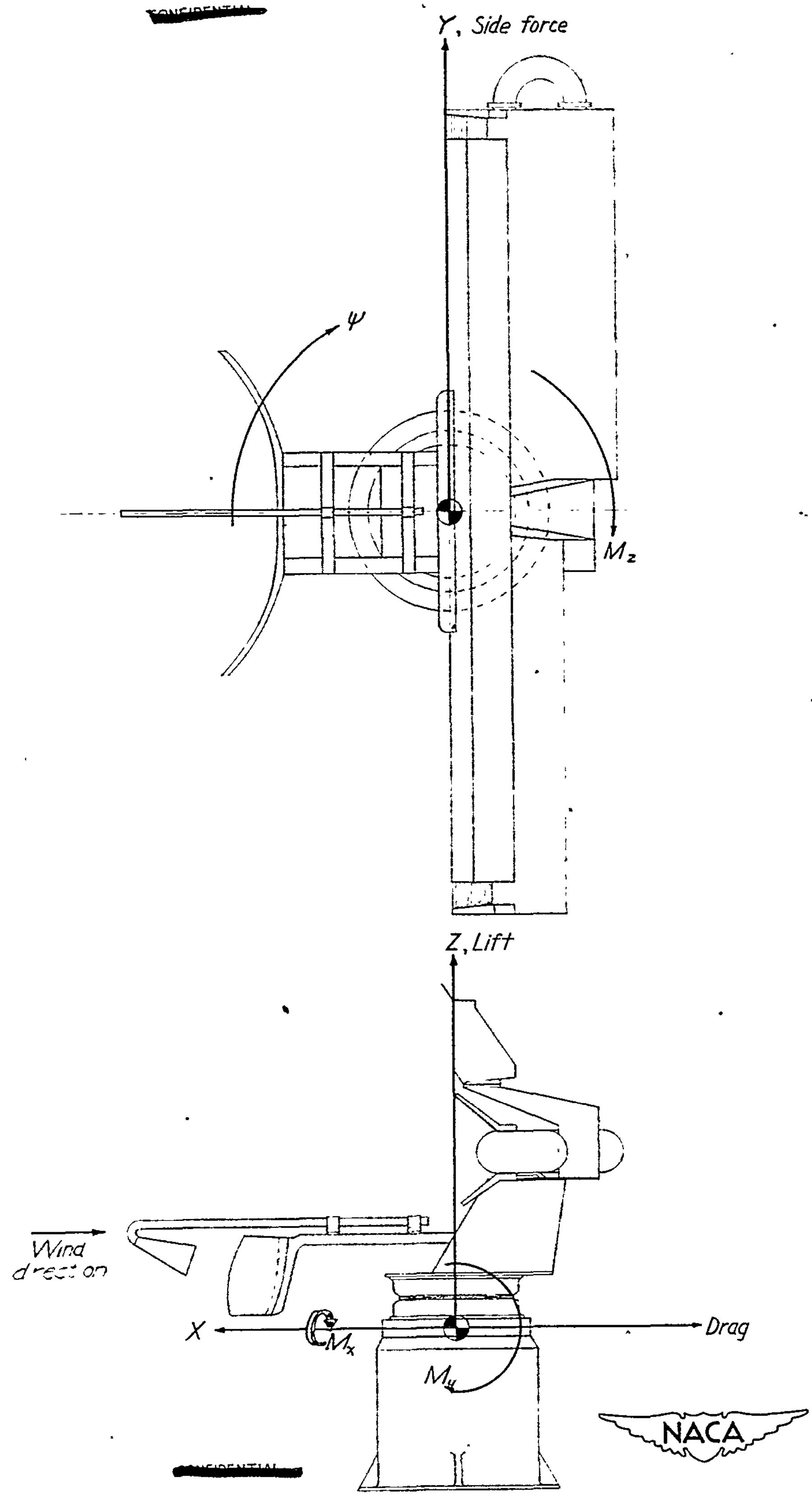

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Figure 1 - System of axes with positive direction of forces, moments, and angles indicated by arrows.

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(a) Three-quarter front view, $\psi = 0^{\circ}$.

Figure 2.- The AN/SPS-1 radar antenna mock-up mounted in the Langley full-scale tunnel. Antenna in full back position.

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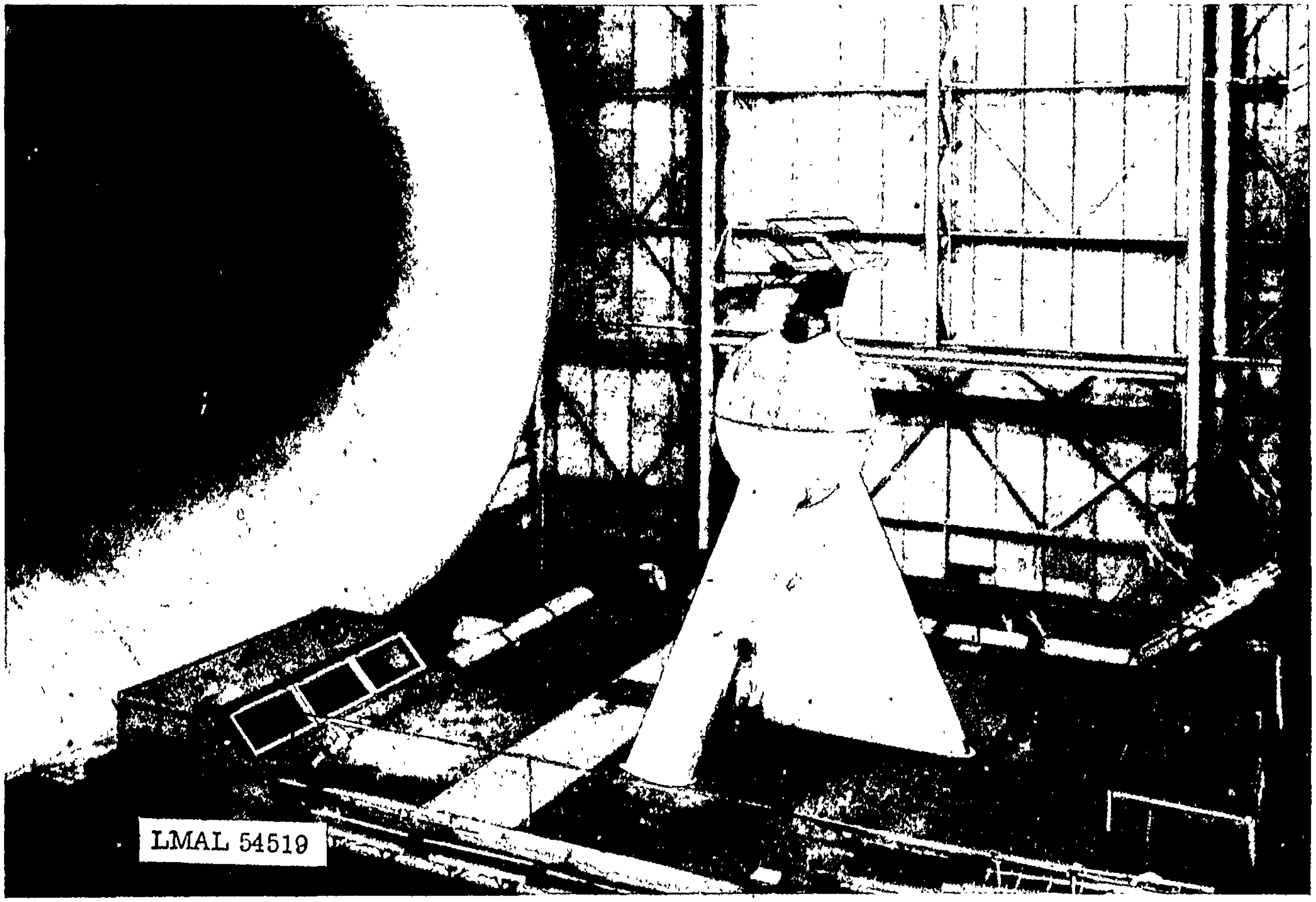

(b) Three-quarter front view, ψ = 180°.

Figure 2.- Concluded.

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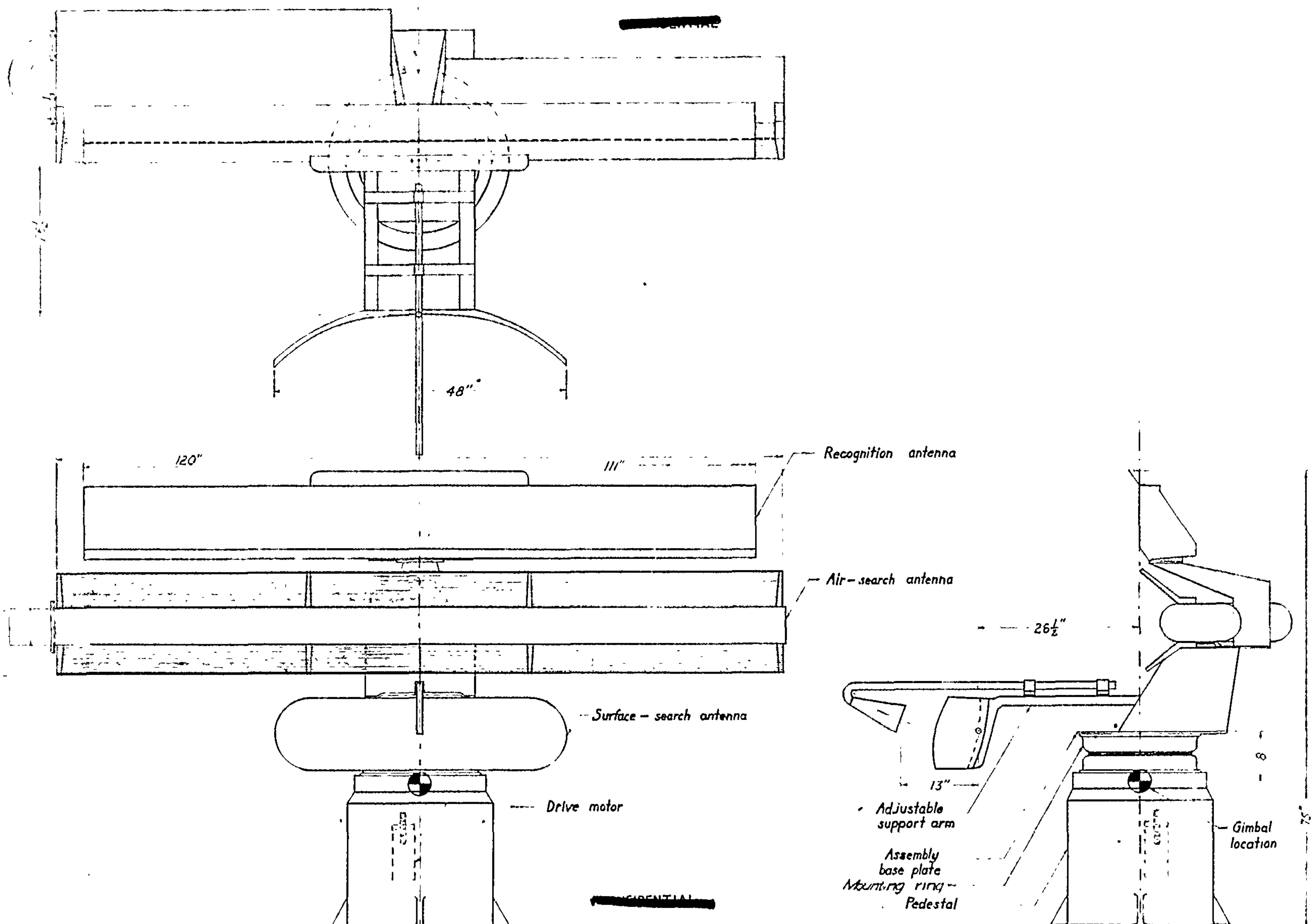

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Figure 3. - Three-view drawing of the AN/SPS-1 radar antenna mock-up

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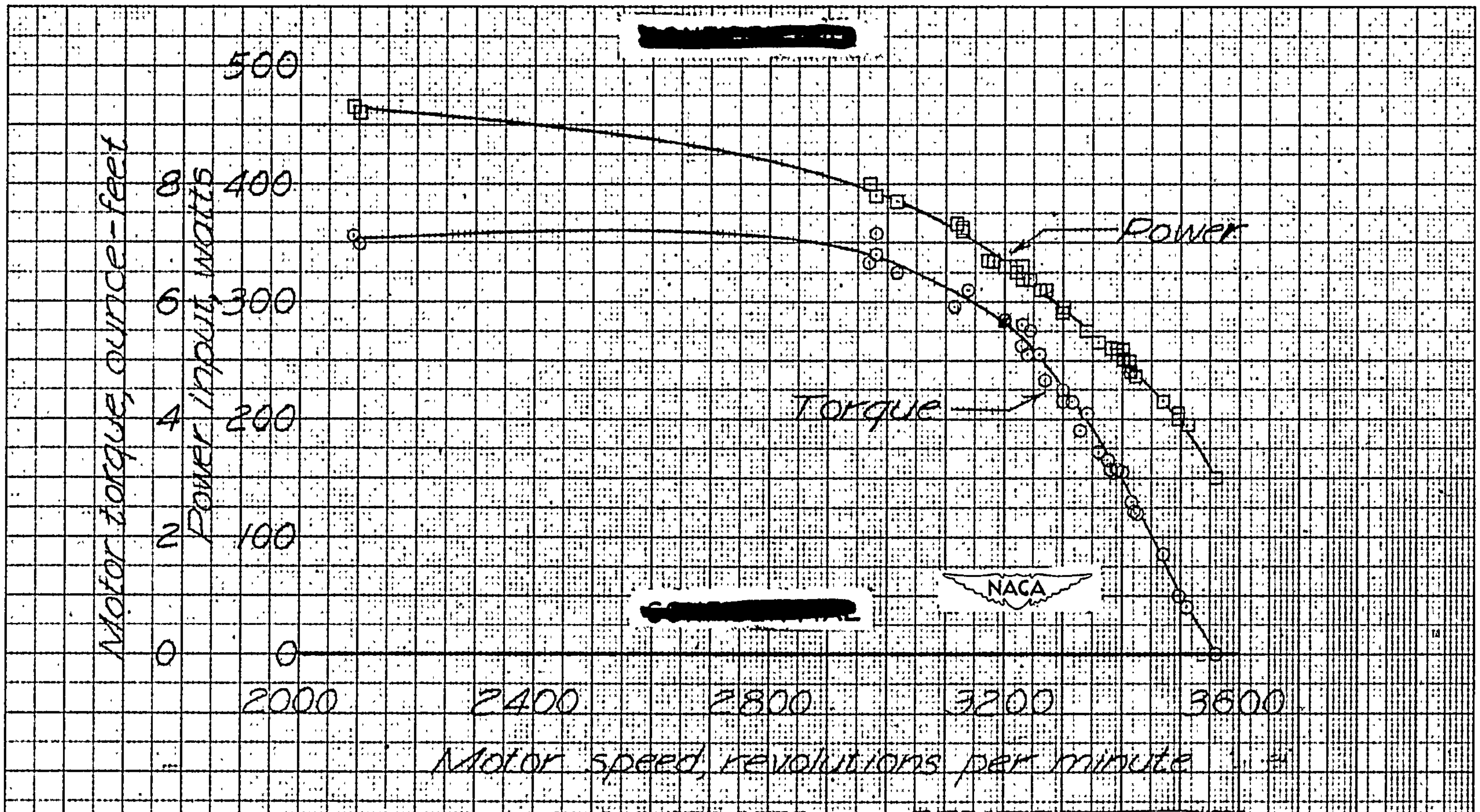

Figure 4. - Drive motor torque - speed and power - speed calibration curves.

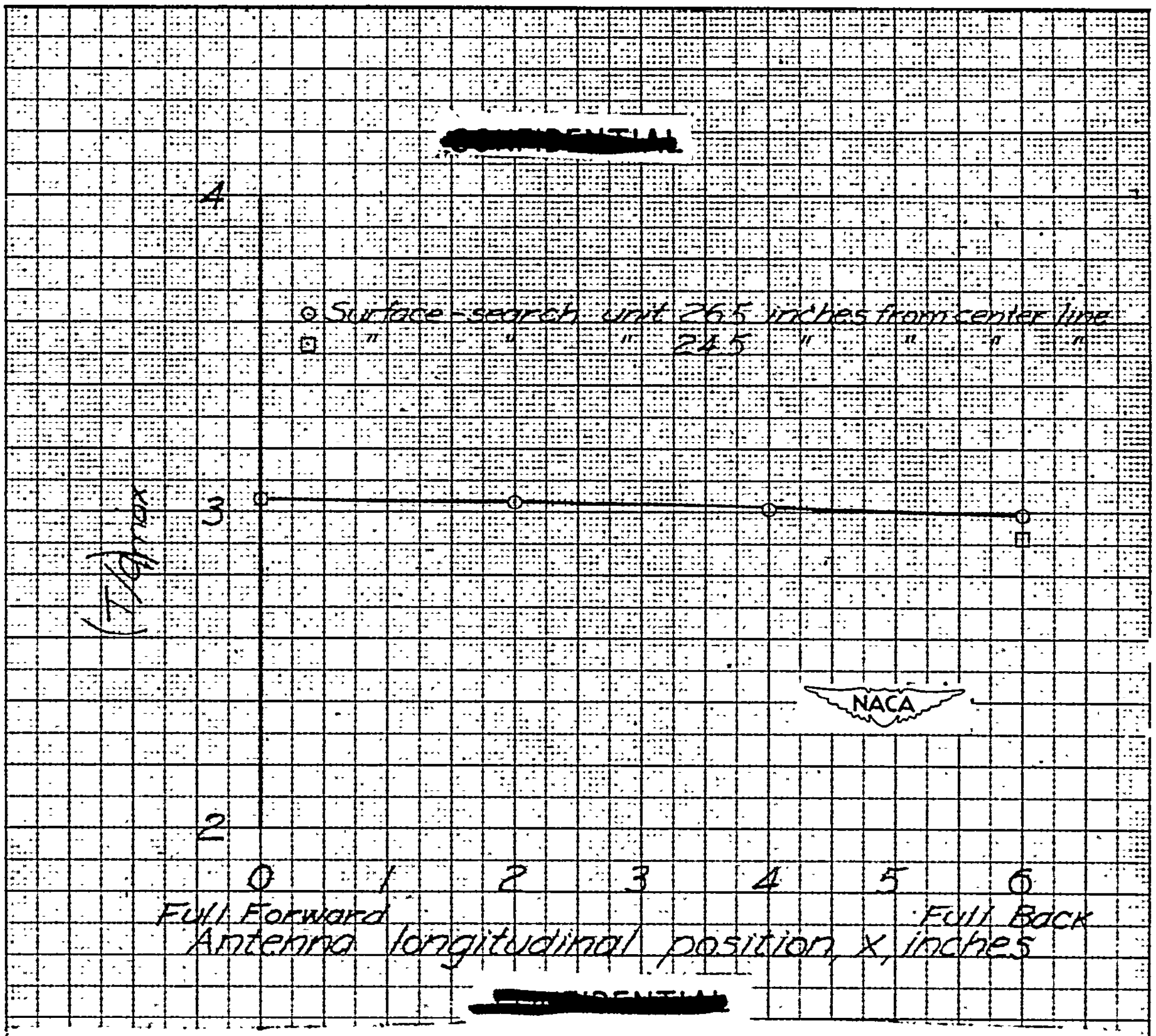

Figure 5.- Variation of maximum drive-motor torque in terms of dynamic pressure with antenna longitudinal position.

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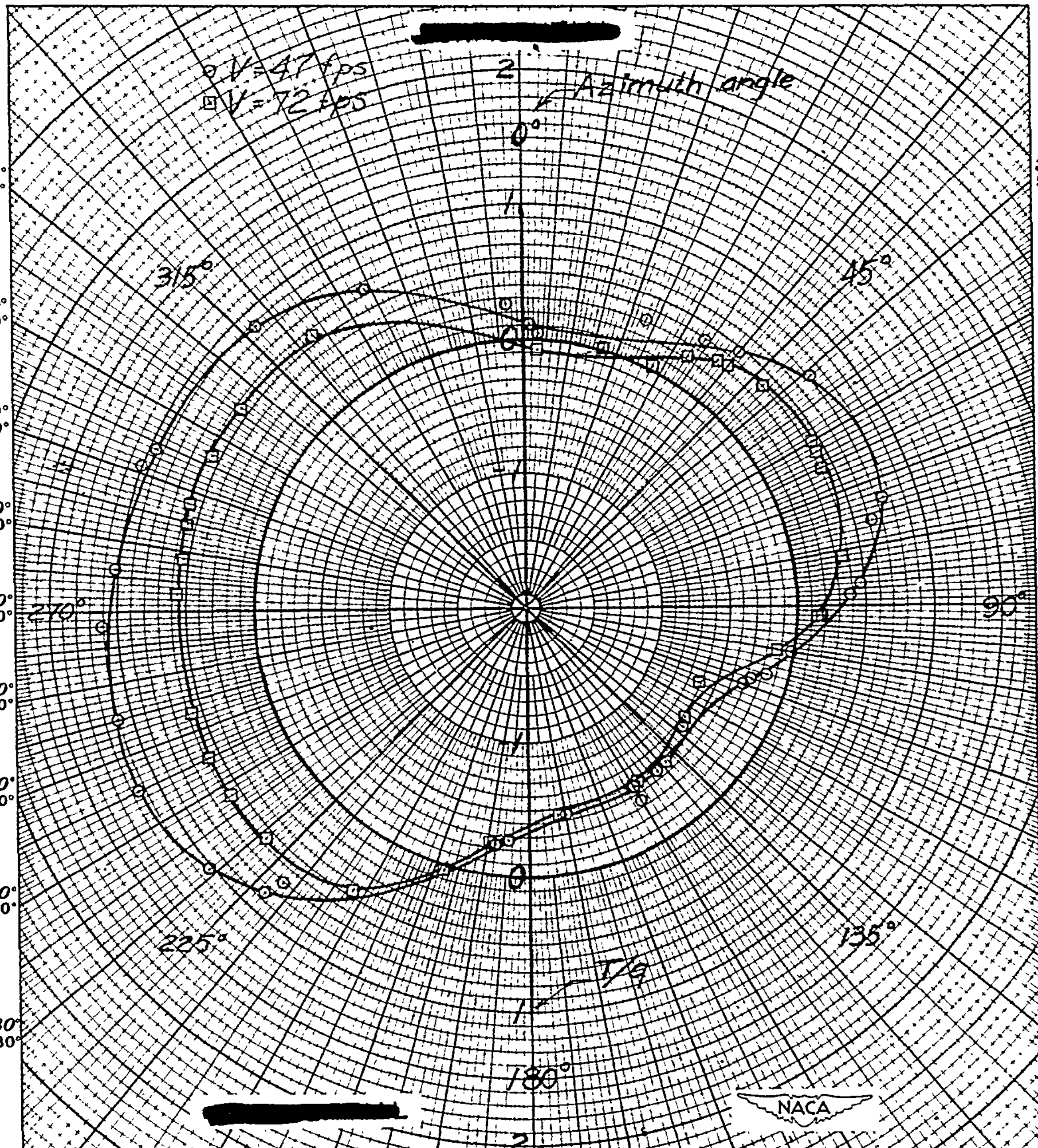

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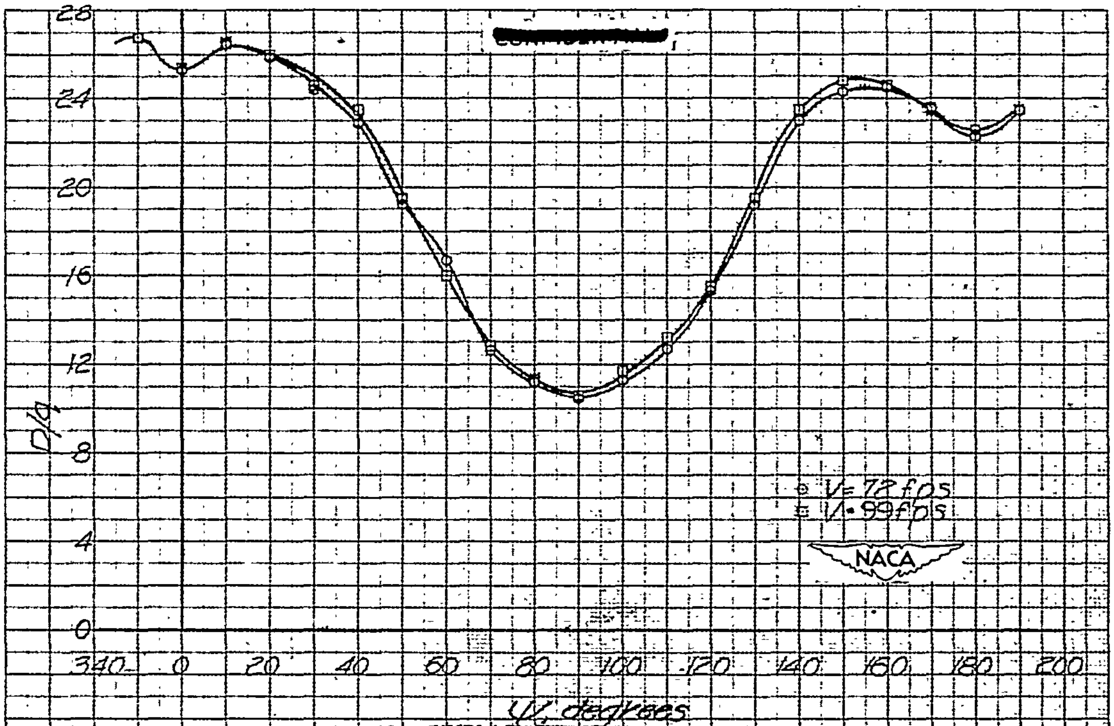
Figure 6.- Variation of drive-motor torque in terms of dynamic pressure through a complete azimuth range.



(a) Drag in terms of dynamic pressure.

Figure 7. - Variation of static forces and moments with azimuth angle.

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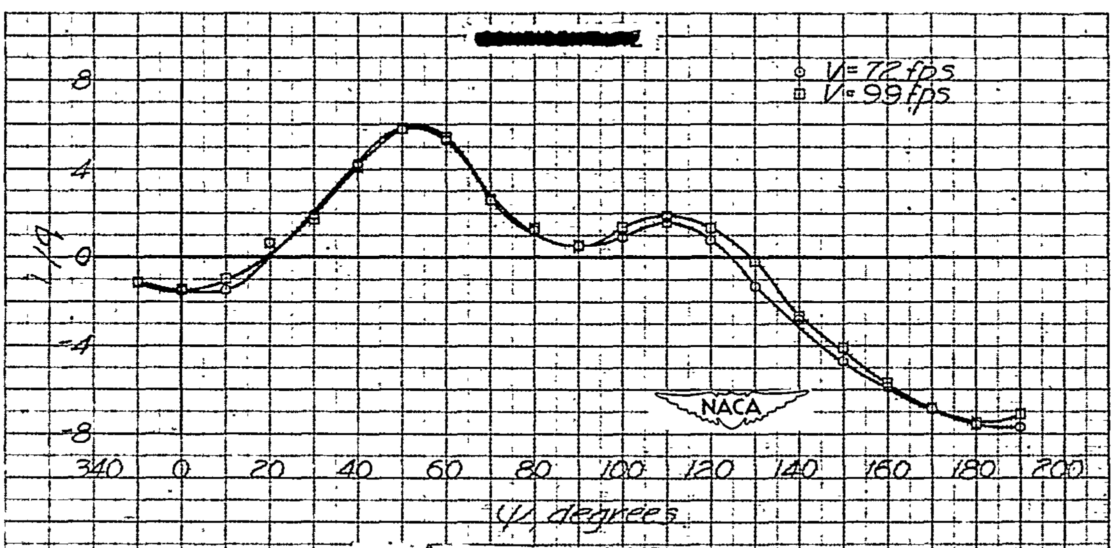

(b) Lift in terms of dynamic pressure.

Figure 7. - Continued

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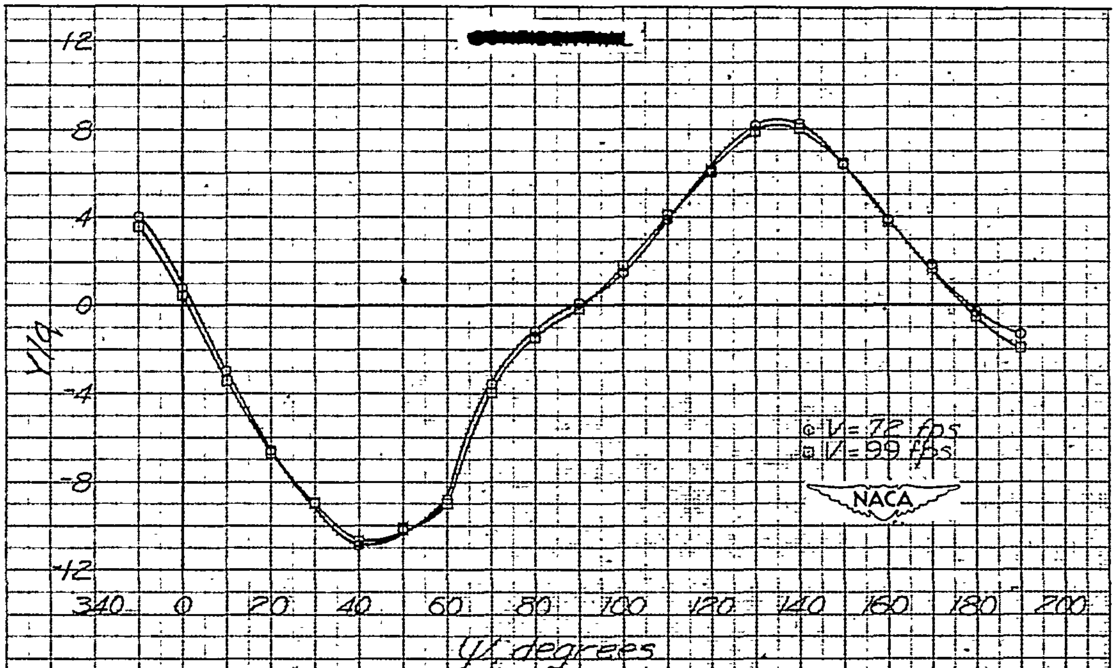

(c) Side force in terms of dynamic pressure.

Figure 7.- Continued

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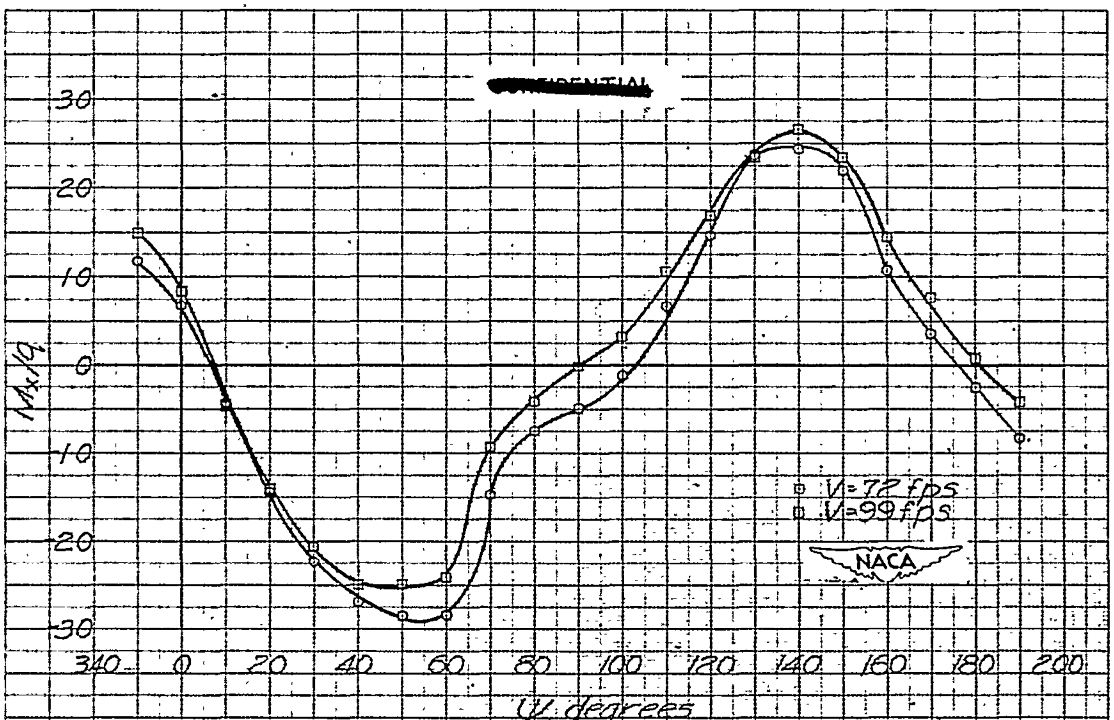

(d) Rolling moment in terms of dynamic pressure.

Figure 7.- Continued.

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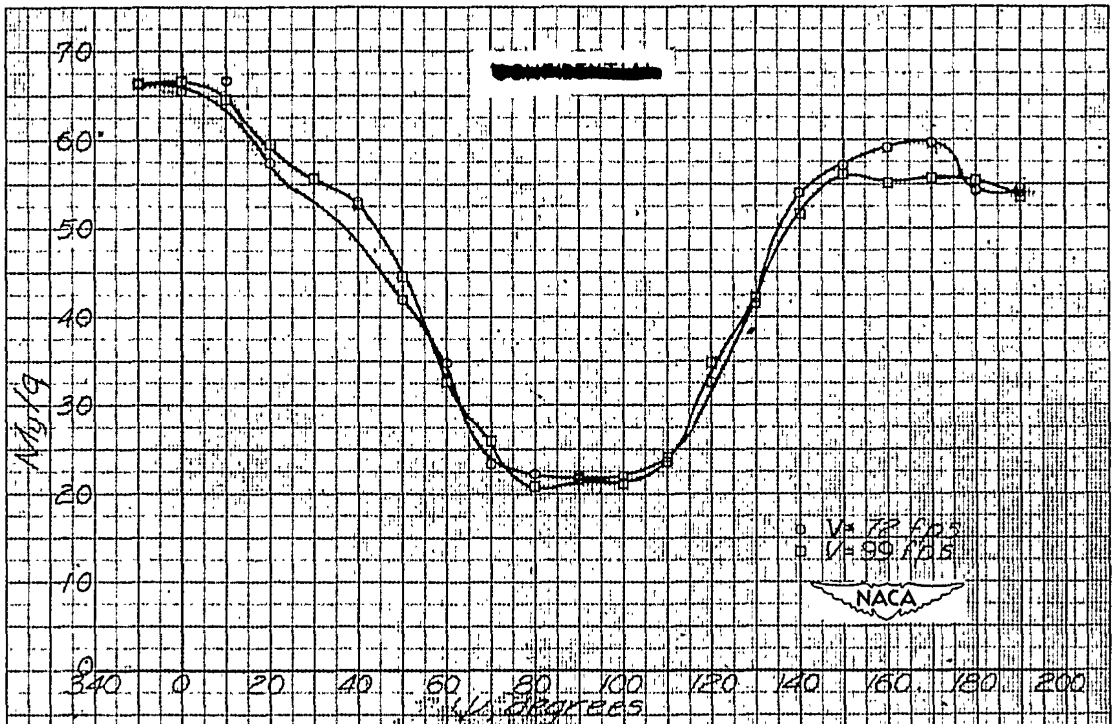

(e) Pitching moment in terms of dynamic pressure.

Figure 7.- Continued.

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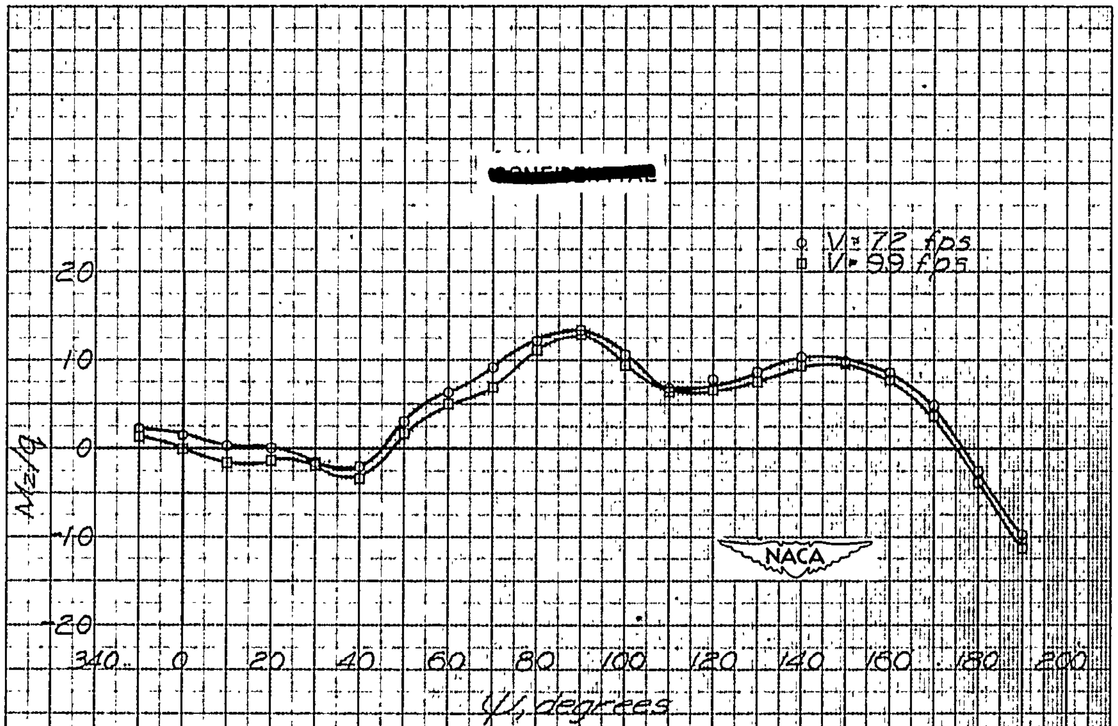

(f) Yawing moment in terms of dynamic pressure.

Figure 7.- Concluded.

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